THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 57, No. 10, December 1978
Printed in U.S.A.

Transaction Network, Telephones, and Terminals:

Physical Design

By D. D. BANKS, G. A. BHAT, and J. W. WESNER

(Manuscript received June 6, 1978)

Physical designs of Transaction I and II telephones and Transaction III terminal are described and illustrated. All three sets feature new card reader designs and a click-disk switch design. These designs are described in detail. Use of these designs in Transaction sets has helped to meet performance, reliability, and cost objectives.

I. INTRODUCTION

A field trial was conducted in the state of Ohio in late 1973 to establish the market potential for a Transaction telephone. Thirty-four sets were installed in 13 merchant locations in Cleveland and Akron for credit verification. The set used in the field trial is shown in Fig. 1. In addition to the parts associated with a telephone, the field trial set contained a motor-driven card reader and electronics required for the card reader and other functions. Instruction lamps, along with brief operating instructions and pockets for storing dialing cards, were located on the front of the set. Some sets also contained a numeric display of information entered from the *TOUCH-TONE®* dial. The field trial experience established the need for a more reliable card reader, a display of not only locally generated information but also an authorization code generated by the data center computer, and a button to permit correction of manually entered information. In addition, the trial established the usefulness of instruction lamps and instructions, and the importance of making the Transaction telephone set as small as possible, since the space where the sets are likely to be located is at a premium.

Utilizing field trial experience, the design of production Transaction telephones began in early 1974. Packaging the electronics of one of the most sophisticated telephone sets the Bell System has ever introduced was a challenge heightened by space and development time constraints.

Fig. 1—Transaction telephone used in field trial.

Transaction II, for example, contains a microprocessor, card reader, data receiver, power supply, numeric display, electronics for a hands-free feature, and a keyboard, all inside a low-profile housing with base dimensions of only 9 in. by 12 in. All three Transaction telephones were designed and introduced in the market in approximately $2\frac{1}{2}$ years.

All Transaction telephones are in similar housings to maintain a family appearance and to minimize costs. The sets follow the current philosophy of offering business telephone sets in only one color and providing color accent with colored faceplates; the Transaction telephone faceplates are offered in eight different colors.

Transaction I and II also share the same card reader, some of the printed circuit boards, and some internal hardware. This has also resulted in reduced development time and in cost savings.

II. CONSTRUCTION

2.1 Transaction I, II, and III sets

The Transaction I, II, and III sets are shown in Figs. 2, 3, and 4. An important difference between Transaction I and II and Transaction III is that I and II function as telephones even in case of power failure, whereas III does not provide a telephone function at all. Transaction III

Fig. 2—Transaction I set.

is designed to be connected via private lines to TNS (Transaction Network Service). In Transaction I and II, the telephone function is provided by a *TRIMLINE*® handset that performs all the telephone functions except for ringing and line switching. The choice of the *TRIMLINE* handset has not only saved internal space, some of which otherwise would have been occupied by telephone components, but it also provides the option of rotary or *TOUCH-TONE* dialing without any space penalty.

The faceplate layouts of all three Transaction sets were based on human factors studies and are designed to assure easy operation of the sets and to minimize operator errors. The instruction lamps, response lamps, and call progress lamps located on the faceplates guide the operator through the transactions. Abbreviated operating instructions appear alongside the instruction lamps. It was assumed that the operator would be familiar with the operation of the set, and these instructions serve only to prompt the operator of the next step. A comprehensive operating procedure is described in a "How to Use" booklet supplied with every set.

A manual entry pad located in the lower half of the faceplate on all three sets consists of an array of click-disk switches similar to the ones used in some hand-held calculators. These switches were chosen because of their long life and low profile. A more detailed description of the pad is given in Section IV.

Fig. 3—Transaction II set

The card reader located at the back of Transaction I and II consists of a "slot" in which a conventional magnetic head, a spring, and a switch are located. A card is read by passing it through the slot oriented so that the magnetic stripe passes along the face of the head. The card reader used in Transaction III uses a magnetoresistive read head instead of the conventional magnetic head. A detailed description of the two card readers is given in Section III.

There is sufficient similarity in the electrical design of Transaction I and II that several printed circuit boards (PCB) are common to both these sets. This commonality has helped reduce cost. Transaction I contains four printed circuit boards which provide a four-chip microprocessor with peripheral electronics, the power supply, the manual entry pad, and electronics associated with the card reader. Two voltage regulators and a transformer associated with the power supply are mounted on a heat sink located at the back of the set. Transaction II, which is more sophisticated than Transaction I, contains additional electronics, viz., a data receiver, an eight-digit, seven-segment numeric display, and electronics required for a hands-free feature. Incorporating the additional electronics in the same housing used for Transaction I presented a difficult problem. The additional electronics meant more power consumption, which presented a challenge in heat sink design. Under the worst-case conditions (i.e., line voltage of 129 volts and all 8's on the numeric display), the power to be dissipated in the heat sink is 15 watts

Fig. 4—Transaction III set.

while operating in the required maximum ambient temperature of 120°F. From a human engineering viewpoint, the temperature of the exposed heat sink should not exceed 140°F (a temperature considered too hot to touch). After the fin thickness and spacing were optimized, it would have been necessary for the heat sink fins to be approximately 2 in. long to achieve a fin temperature below 140°F; this would have violated size constraints and also have been aesthetically unacceptable. The selected compromise was to allow the heat sink to reach a temperature of 163°F (which could be achieved with fins only ¾ in. long) and to enclose the entire heat sink in a vented plastic cover to prevent direct user contact with the too-hot surface.

Electronics in Transaction III are packaged on six printed circuit boards which contain a five-chip microprocessor and peripheral electronics, a modem, a numeric display, a manual entry pad, and a power supply. Since the power consumption of Transaction III is approximately the same as Transaction II, it uses the same heat sink and cover arrangement.

2.2 PIN pad

A PIN pad, shown in Fig. 5, provides a means for entering a personal identification number (PIN) during a transaction. Since the PIN pad is a field-installable adjunct to all three Transaction sets, it is available in

Fig. 5—PIN pad.

the form of a kit. The kit consists of a click-disk dial assembly, a cord, and a push-on/push-off key. (The added push-on/push-off key is not required in Transaction III because this function is performed by a switch integrated with the manual entry pad.) The push-on/push-off key, which mounts in the Transaction set, allows the operator to enable the PIN pad at the appropriate time during a transaction.

III. CARD READER

The card reader used in the field trial set was an electromechanical reader purchased commercially which contained a motor-driven rubber roller that pulled the card into the reader and moved the card past a fixed magnetic head at constant speed. A microswitch located at the back of the reader reversed the motor to return the card. The reader was expensive and did not meet reliability objectives; occasionally a card, especially one which had become dirty or wet, would not be returned to the user.

To avoid the problems of a motor-driven reader, an electronic technique was developed that permitted reading of cards over a wide range of speeds and speed variations. This technique simplified the physical design of the card reader considerably. A reader was designed that consists simply of a slot containing a magnetic head, a spring to maintain the proximity of the card to the head, and a switch; a card is read by manually passing it through the slot. The switch initiates the electronics when the card reaches the proper position with respect to the head. The reader has no moving parts (other than the switch actuator) and is quite insensitive to bent cards. The cost of the reader is also considerably less than any known alternatives. The "slot" reader was introduced in an early design of Transaction telephone; the set with this first slot reader is shown in Fig. 6. Human factor evaluations of this reader showed an error rate of only 2.4 percent on the first try.

Fig. 6—Transaction set with first slot reader.

3.1 Transaction I and II card reader

The slot reader as redesigned for the production sets is shown in Fig. 7. In this reader, the card moves in a vertical plane—a better position from a human factors standpoint than the first, sloping configuration. The reader housing also contains pockets for storing dialing and test cards.

3.2 Transaction III card reader

3.2.1 Construction

The card reader used in Transaction III employs a new technology: a magnetoresistive read head instead of the conventional magnetic split-ring read head. Pictures of the reader and the read head are shown in Figs. 8 and 9. Another improvement accommodates the printed circuit board containing the reader electronics in the reader housing rather than within the main part of the set. This feature has faciliated testing at manufacture, and troubleshooting and repair in the Western Electric repair centers.

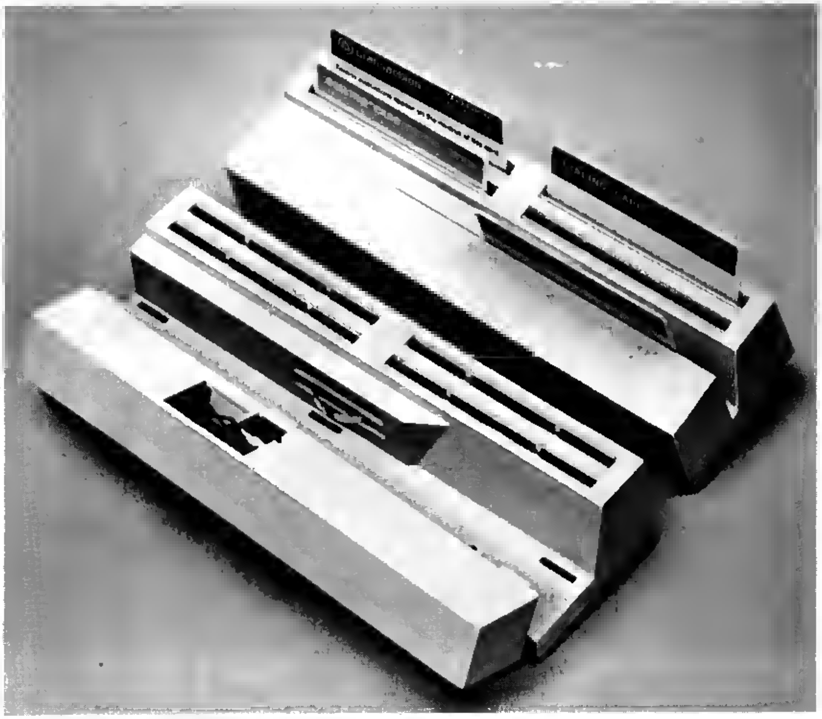


Fig. 7—Slot reader designed for production.

3.2.2 Read head

The magnetoresistive read head consists of a plastic holder and a ceramic chip (see Fig. 10) which contains two stripes of permalloy magnetoresistive material. Connections to the stripes are brought to the back side of the chip via feed-through holes, and leads are bonded to lands connected to the feed-through holes. The "stripe" side is coated with an acrylic material to protect the permalloy from wear.

Assembly of the chip in the holder is critical in that the exposed chip surface must be flush with the front surface of the holder. This has been accomplished by coordinated design of the holder and a special assembly fixture.

IV. MANUAL ENTRY PAD

4.1 Construction

The manual entry pad in all Transaction telephones consists of an array of click-disk switches. Construction of a typical click-disk switch is shown in Fig. 11. The two outer "staples" and the center "staple" form the contacts of the switch, and the dome-shaped disk acts like a switch arm. In the free position, the disk makes contact only with the outer

Fig. 8—Transaction III card reader.

staples. When sufficient force is applied to the disk, it buckles and makes contact with the center staple. The buckling action of the disk provides a tactile feedback to the switch. Nominal operate force of the switch is about 180 grams.

The click-disk switches were selected for the Transaction telephones for the following reasons:

(*i*) Long life—greater than 2 million operations.
(*ii*) Low profile.
(*iii*) Printed circuit board construction permits integration of the keyboard with other electronics. While it somewhat complicated the keyboard assembly, this approach (which was unique at the time of its introduction) eliminated the need for, and cost of, a separate terminal board.
(*iv*) Tactile feedback.
(*v*) Low incremental cost for additional switches. This has proved to be advantageous in Transaction II and III; costs of the additional control keys in these sets were small.

Fig. 9—Transaction III read head.

4.2 Human factors

Dials using click-disk switches were tested for dialing speed and accuracy. Click-disk dials with various button travels were tested, along with a regular *TOUCH-TONE* dial. The study concluded that, even though the *TOUCH-TONE* dial was preferred over all others (especially by subjects familiar with *TOUCH-TONE* dialing), the speed and error rates associated with use of the click-disk dials were not significantly different from those of the *TOUCH-TONE* dials.

4.3 Bounca

Even though the click-disk switches exhibit almost no detectable "bounce" when firmly depressed, they do exhibit a "bounce" problem if the buttons operating them are "tapped" or "teased." This bounce could cause double digits, unless it is compensated for by the electronics reading the keyboard.

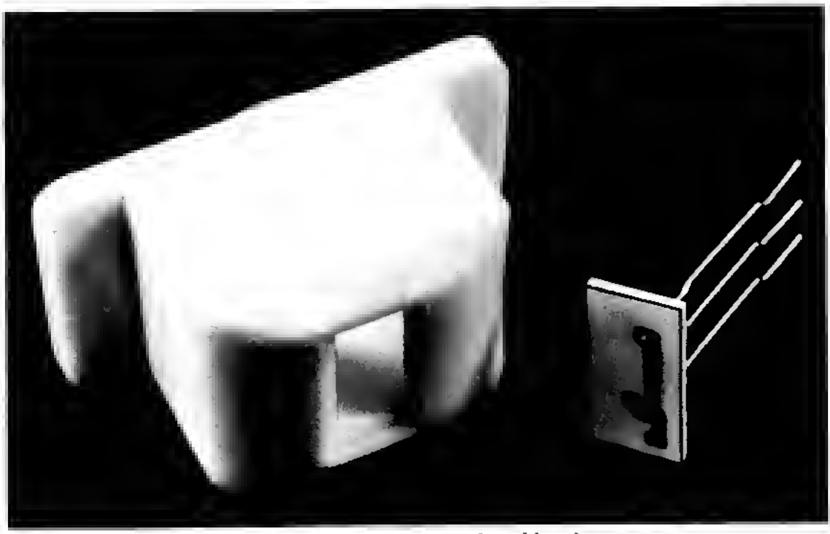
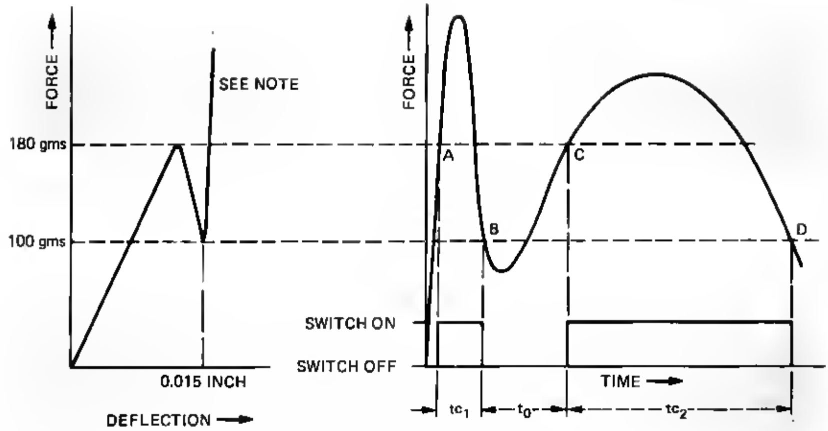


Fig. 10—Components of read head.

Fig. 11—Click-disk switch.

The bounce occurs because of the characteristics of the force applied by the finger, especially when the force is applied perpendicular to, rather than along, the axis of the finger (Fig. 12). The force-deflection curve for the disk is also shown in Fig. 12. When the applied force exceeds the



NOTE: AFTER THE DISK BOTTOMS ON THE CENTER STAPLE, THE SLOPE DEPENDS ON THE MANUAL ENTRY PAD SUPPORT.

Fig. 12—Click-disk switch force deflection characteristics.

"operate" force (point A), the disk buckles and the switch closes; when the applied force drops below the "release" force (point B), the disk begins to restore and the switch opens. Complete recovery of the disk depends upon how far the applied force drops below point B and how fast it builds up again. In any case, the switch definitely closes again when the applied force again exceeds the operate force (point C). The switch opens once again when the finger is lifted (point D). The first closure (tc_1) is typically 5 to 10 ms long, and the open period (t_o) is typically 2 to 30 ms long. The second closure (tc_2) is typically greater than 5 ms. Programming the microprocessor not to look for a switch closure for slightly more than 30 ms after a valid closure is detected eliminated the possibility of identifying the bounce as a second valid switch closure.

V. SUMMARY

The key to successful introduction of three Transaction sets in approximately 2½ years was in maintaining commonality of several components among the three sets. This commonality of parts helped to expedite the designs and minimize costs.

A new card reader which is simple to use, reliable, and inexpensive was introduced in these sets. Application of a new Bell System-developed magetoresistive read head technology has helped to further reduce the cost of the card reader. Click-disk switches, which are of non-Bell System design, were introduced in telephone sets for the first time in the Transaction sets. Their use has facilitated design while maintaining high reliability. Both the card reader and the click-disk switches have been well received in the field. The Transaction sets, which were originally intended for credit verification, are finding other applications in the

financial industry—including use as a check-cashing terminal and a lobby terminal in banks where customers can determine their bank balances without seeking teller assistance. The sets have generally performed very well in all these applications.